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Technical Report No. 136

THE SPIN-UP IN PRECIPITATION AND EVAPORATION OF GLOBAL AND LAM UNIFIED MODEL FORECASTS JANUARY 1992-MAY 1994

by

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October 1994

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1. INTRODUCTION

Most numerical weather prediction (NWP) models display a characteristic "spin-up" in certain quantities when integrated from an initial state generated from an assimilation of observations and model background field. This spin-up is most often associated with the model hydrological cycle and usually represents an adjustment of the model fields from an unbalanced initial thermodynamic state towards a physical/dynamical balance. Such a spin-up usually occurs on a relatively short timescale of 3-4 days and as such can be distinguished from the "Climate Drift" of the models planetary scale mass and wind fields which achieve balance on longer timescales. Such initial adjustments in an NWP model can arise not only from imbalance in the initial state but also from deficiencies in modelling the physical and dynamical processes in the model. In the latter case a typical scenario leading to a spin-up may be that the thermodynamic state required by the model's convection or large scale cloud schemes is incompatible with that of the initial analysis, in which case the adjustment process represents a drift towards the model's preferred but unrealistic climate. Differentiating between adjustment due to deficiencies in the initial state and in the model's representation of physical/dynamical processes is difficult, and is further compounded by the fact that the model itself is a key component of the data assimilation process.

The aim of this note is to document the spin-up observed in precipitation and evaporation accumulations from the operational forecasts of the global and limited area (LAM) versions of the Unified model (UM) over a two and a half year period. Understanding the nature of the spin-up in the hydrological cycle and its seasonal variation is of particular interest as recent diagnostic studies of the thermal budget (Milton, 1993) suggest the spin-up may be related to the cooling bias in the UM. Deficiencies in precipitation lead to errors in the planetary scale diabatic heating field which may impact upon subsequent forecast development, particularly in the tropics and stormtrack regions where diabatic heating is large. This investigation of the UM spin-up expands on earlier studies of the spin-up in connection with data assimilation by Lorenc (1992). Section 2 describes the data used in this study. Section 3 deals with the spin-up in the global UM whilst section 4 shows a comparison of the global and LAM versions of the UM in order to assess the role of horizontal resolution in the model hydrological cycle. Conclusions are drawn in section 5.

2. DATA

The precipitation and evaporation fields are from operational forecasts of the global and LAM models run from 00Z and 12Z analyses covering a two and a half year period from January 1992 to May 1994. Monthly averages have been formed from the daily time series of forecast accumulations of precipitation/evaporation over the model assimiliation (T-06 to T+00 for the global model) and between various forecast ranges (e.g. T+24 to T+48). All monthly means are expressed in the units of $kg/m^2/day$. However the accumulation periods shorter than 24 hours do not cover a full diurnal cycle . For example the 6 hour assimilation period only covers the hours 18Z-00Z and 06Z-12Z. This must be borne in mind when interpreting the model spin-up.

During this period there have been two major changes to the operational global UM formulation. These were;

March 1993 - Change from 2nd order moisture diffusion ($\nabla^2 q$) to 4th order ($\nabla^4 q$).

January 1994 - Implementation of the "Frozen Physics" package (Hammon and Wilson, 1993).

The "Frozen Physics" package and its impact on the operational forecasts is discussed in the above reference. The two major features of this package were the inclusion of downdraughts in the convection scheme and the addition of a non-local turbulent mixing criterion for temperature and moisture in the boundary layer scheme to improve mixing in unstable conditions (Smith 1993).

3. SPIN-UP IN GLOBAL UM FORECASTS

3.1 *Characteristics of the spin-up in the UM*

We begin by examining the typical spin-up from one month of UM global forecasts. Figure 1 shows the zonally averaged precipitation/evaporation rates (in $kg/m^2/day$) from a series of one timestep forecasts (62 in total) run from T+00 and T+72 model dumps for July 1993. These runs were originally carried out to study the thermal budget (Milton, 1993). The total precipitation (Fig. 1(a)) shows a clear increase in mid-latitudes and a slight decrease in the tropics between T+00 and T+72 and. In the Northern Hemisphere (NH) there is almost a doubling in the precipitation rate. The globally averaged precipitation rate increases from 2.33 to 2.80 $kg/m^2/day$. The contribution to this spin-up from the large-scale (dynamic) and convective *rainfall* is given in figures 1(c) and 1(d) respectively. The globally averaged large scale rain shows a 44% increase between T+00 and T+72 whilst the convective rainfall shows a 15% increase.

The globally averaged evaporation rate (Fig 1(b)) remains fairly constant with forecast range at ~2.9 $kg/m^2/day$. However, examination of the variation of evaporation with latitude band reveals a large decrease in the NH mid-latitudes (30N-60N) which is offset by an increase in the tropical belt. This is further discussed in section 3.3.

3.2 *Global Climatology of Precipitation and Evaporation*

For long period time-means the global values of precipitation minus evaporation (P-E) should be close to zero. This provides us with a useful global measure of the hydrological balance at various forecast ranges in the UM. Figure 2 shows the monthly averaged time series of P-E plotted as a function of forecast range. It is clear that the UM forecasts do not begin from a state of hydrological balance. During the assimilation there is a deficit of precipitation compared to evaporation and as the forecasts progress P-E, approaches zero as the model moves towards equilibrium. However equilibrium is still not reached after 3 days. There is a jump in this time series in March 1993 which coincides with the operational implementation of fourth order diffusion of moisture ($\nabla^4 q$). This change has a beneficial impact upon the spin-up in global P-E reducing the deficit of precipitation in the assimilation. For example the table below shows the in P-E values in 3 successive Mays.

	MAY 1992	MAY 1993	MAY 1994
P-E (kg/m2/day)	~-0.8	~ -0.5	~ -0.6

The globally averaged precipitation (Figure 3(a)) shows that the spin-up in the UM is present in all seasons with no obvious indication that it is worse in one season compared to another. The change to $\nabla^4 q$ in March 1993 can clearly be seen and increases the precipitation in all forecast ranges and reduces the spin-up observed between the assimilation and later forecast ranges. For example compare values of precipiation in figure 3(a) for July 1993 and July 1992. It is also apparent that both precipitation and evaporation (Fig 3(b)) values for MAM 1994 are considerably higher than MAM 1993 which may be a result of the implementation of Frozen Physics in January 1994. Also plotted on figure 3(a) are the monthly-mean values of globally averaged precipitation from the climatology by Jaeger (1976). Prior to March 1993 the UM global precipitation is considerably less than the Jaeger climatology in the early stages of the operational forecasts and does not approach the climatology until T+48 to T+72. This suggests that the model was severely lacking in precipitation in the first few days of the operational forecast during this period, although it must be borne in mind that there is not good

agreement between various climatologies of precipitation. After March 1993 we see the model precipitation is much closer to the climatology during the assimilation period and is greater than the climatology in the later forecast ranges. The evaporation shows a smaller spin-up than precipitation although there is more seasonal variation in the evaporation spin-up with the largest adjustments in September-February and smallest in March-August. In general the evaporation rates are closer to the Jaeger precipitation climatology than the precipitation rates.

Finally we consider the geographical distribution of precipitation. The model precipitation during the assimilation (T-06 to T+00) for DJF 1992/93 and 1993/94 is contrasted with the Jaeger climatology in Fig. 4. The model has a good representation of the main features including a well defined ITCZ and SPCZ (South Pacific Convergence Zone), although in general the tropical precipitation is higher than in Jaeger. This can be seen over the Indian Ocean, West Tropical Pacific and East Tropical Pacific. An exception is the Amazon Basin where model precipitation is considerably less than the Jaeger climatology in both 1992/93 and 1993/94. In mid-latitudes the model has higher precipitation in the NH stormtracks, but less in the SH stormtracks, and over the land masses. The model precipitation also has a large number of high values associated with the orography such as the Andes and Himalayas which do not appear in the climatology. The reality of such features cannot be determined, but given the presence of the large spikes in precipitation in the zonally averaged fields (Fig. 1 at 30N) it is felt that these orographic features may be overestimated.

In JJA (Fig. 5) the model has captured the northward shift of the ITCZ with season. However the structure of the model ITCZ is quite different to that in the climatology, with precipitation concentrated in the East Pacific Ocean at 10N, whereas in Jaeger it is a maximum over the tropical land masses of Central America and the Caribbean. Model precipitation is also more intense in the west tropical Pacific region and over Central Africa. An increase in tropical precipitation between JJA 1992 and JJA 1993 is also evident, most noteably in the East Pacific and equatorial Atlantic. This is further discussed in the next section.

As already noted the T+48-T+72 forecasts of precipitation are closer to the Jaeger climatology than those during the assimilation. These fields are shown for DJF 1993/94 and JJA 1993 (Fig. 6) for comparison with those from the assimilation (Fig. 4 and 5). In DJF there is an increase in the precipitation in the NH and SH stormtracks and over the Amazon Basin. The spinup in JJA 1993 is less obvious but careful inspection shows increases in tropical rainfall maxima.

3.3 *Time Series of Precipitation and Evaporation Over Limited Domains.*

We now focus upon the seasonal and geographical variability in the precipitation/evaporation spin-up. Figures 7-11 show time series of the monthly averaged precipitation/evaporation fields at various forecast ranges through two and a half annual cycles from January 1992 to May 1994 for each of the following geographical domains

1. Tropics. (15N-15S)
2. Northern hemisphere. (30N-90N)
3. Southern hemisphere. (30S-90S)
4. Europe. (10W-40E, 40N-70N)
5. Atlantic. (75W-15W,30N-60N)

The tropics (Fig.7) shows many of the spin-up features noted for the global domain. The impact due to the change to $\nabla^4 q$ is even more marked in the tropics with a clear step up in the precipitation after March 1993. There appears to be no clear signal of the change to frozen physics in January 1994. The decrease in tropical precipitation noted in figure 1 is not present in this time series as it is a localised feature which does not show up in the wide latitude band chosen for the tropics (15N-15S). The evaporation shows a spin-up throughoutnthe year with a minimum in Feb-March and maximum in JJA. The evaporation spin up is smaller in magnitude than that in the precipitation.

For the NH precipiation (Fig. 8(a)) the impact of introducing $\nabla^4 q$ is not as marked as in the tropics, although there is greater precipitation in JJA 1993 compared to JJA 1992. Again we see a considerable spin-up which does not vary greatly with season. The evaporation (Fig. 8(b)) shows a large seasonal variation with a noteable decrease or spin-down in evaporation during the course of operational forecasts run during the summer months from May-August. Further diagnostic studies have shown that this feature is located over the continental land masses. It is related to a lack of cloud in the initial stages of the forecasts which leads to large incoming solar radiation at the surface which drives the evaporation and ultimately leads to a drying of the model's land surface. As the forecasts progress the cloud itself spins-up and solar insolation decreases, hence the observed decrease in evaporation noted in figure 8(b). This drying over NH continents during JJA is a well known bias in the UM and current operational practise is to only allow the surface hydrology to "run free" in the model for a week at a time before resetting the soil moisture field to climatological values. In contrast there is a smaller increase in evaporation during the course of a forecast in the winter months when solar

insolation is at its minimum.

The SH domain (Fig 9) shows a large seasonal variation with precipitation maxima in May-July. Again a spin-up can be seen which shows some seasonal variation, being largest in May-July when precipitation itself is a maximum. In contrast with the NH we see that the evaporation has a much smaller spin-up. Both precipitation and evaporation rates for May 1994 are larger than those in May 1992 or 1993 which may be a consequence of the change to frozen physics although interrannual variability cannot be ruled out as a cause.

Finally we turn our attention to the areas surrounding the UK. Both the European (Fig 10) and Atlantic(Fig 11) regions show the characteristic spin-up in precipitation. The most noteable difference between the two regions is in the evaporation field with the European region displaying the large decreases during the forecasts in JJA noted for the Northern Hemisphere region, whilst the Atlantic remains more constant with forecast range apart from a small spin-up in Nov-Dec when evaporation is at its largest.

4. COMPARISON OF LAM AND GLOBAL UM SPIN-UP.

In this section we have compared the LAM and global UM forecasts from 00Z and 12Z analyses for one year from Jan-Dec 1993. The aim of this is to discover whether there is a dependence on horizontal resolution in the models hydrological cycle. In order to validate both models over a common area the global forecasts have been interpolated onto the LAM grid. In addition the LAM is only run to 36 hours and hence the two models only have a few accumulation periods in common. We have chosen to show the accumulated precipitation/evaporation over the assimilation period of both models (Global ->T-06 to T+00; LAM ->T-03 to T+00) and over the common forecast range of T+12 to T+24.

Figure 12 shows the precipitation/evaporation time series over the whole LAM area. Considering the precipitation (Fig 12(a)) we see that the LAM has larger values than the global model in both the assimilation and forecast periods. In fact between January and April 1993 the precipitation in the LAM assimilation is larger than that in the global model forecast for T+12 to T+24. Both models show the characteristic spin-up discussed in the previous sections. Similarly the evaporation rates are higher in the LAM with the largest differences between the two models during October-February. Both models show a decrease in evaporation between the assimilation and forecast period which is largest in JJA

and is therefore clearly dominated by the large evaporation over land discussed for the European region.

Finally we show the contribution to the total precipitation from the large scale (dynamic) and convective precipitation (Fig. 13). This shows that the LAM has more precipitation than the global model in both the large scale and convective components. These results demonstrate that there is either a horizontal resolution or timestep dependence on precipitation processes in the UM. A recent study by Stratton (1994) has investigated such timestep dependencies of model physics in the global Unified Model.

5. SUMMARY AND DISCUSSION

To summarise the Unified Model shows a considerable spin up in its hydrological cycle during the course of a 5 day forecast. This spin-up consists of

(i) A global deficit of precipitation compared to evaporation in the early stages of the operational forecasts as shown by globally averaged values of P-E.

(ii) An increase in total precipitation with forecast range in all seasons and all regions. The magnitude of this spin-up is largely independent of season and comparison of globally averaged precipitation with the Jaeger climatology suggests the precipitation is unrealistically low in the initial stages of the operational forecasts.

(iii) The spin-up in evaporation shows more variation with both season and region. Particular features include

- Decrease in evaporation rate with forecast range over NH continents in JJA
- Increase in evaporation rate in the tropics (largest in May-Sept) and SH.

(iv) A sensitivity of the spin-up in precipitation to the order of moisture diffusion used. The spin-up was reduced considerably and precipitation rates increased by the operational implementation of $\nabla^4 q$ in March 1993.

(v) A dependence on horizontal resolution and/or timestep of the precipitation and to a lesser extent the evaporation exists in the UM. The LAM shows higher values of both precipitation and evaporation than the global model in both assimilation and forecasts in all months.

The question raised by this study is whether the deficiency in precipitation in the initial stages of the

forecast is a function of the specification of the initial state or a problem with model physics. It has been suggested that radiosondes reports are unreliable close to saturation showing a tendency to report too dry. This leads to a drying of the model atmosphere during assimilation, insufficient precipitation , drying of land surfaces, and ultimately a large spinup in the models hydrological cycle. Recent changes to the assimilation cycle have been tested which account for the drying of radiosondes by conserving RH during assimilation and applying a 'boost' to the RH reported from sondes close to saturation (Bell, 1994). This leads to a reduction in the spin-up during the assimilation, and in the 0-12 hour range of LAM forecasts. However a residual upward trend in precipiation and cloud amounts remains, which suggests problems with model formulation.

6. REFERENCES

Bell, R.S., 1994: Moisture spin-up - a possible solution. *FR Technical Report N0 90.*

Hammon, O.H. and Wilson, C.A., 1993: Global forecast model trials of revised "Frozen" physics - *FR Technical Report N0 76.*

Jaeger,L. 1976: Monthly precipitation maps for the entire earth. *Bericht Deutscher Wetterdienst 18. Nr 139, 38pp*

Lorenc, A., 1992: Assimilation of Satellite Data in Models for Energy and Water Cycle Research. *FR Division Scientific Paper No. 8.*

Milton, S.F., 1993: Diagnosing Sytematic Errors in the Unified Model. I- Thermal Budget. *FR Division Technical Report No. 64.*

Stratton, R.A., 1994: An Investigation of the Sensitivity of Model Physics to Timestep at Standard Climate Resolution. *Hadley Centre Internal Note No. 60.*

7. Figure Captions

Figure 1 Zonally averaged hydrological budget at T+00 and T+72 calculated from one timestep integrations run during July 1993. Values given are the precipitation /evaporation rates over one timestep averaged over 62 forecasts run from 00Z and 12Z and scaled to units of $kg/m^2/day$. (a) Total Precipitation (Large-scale raind+large-scale snow+convective rain+convective snow;(b) Evaporation; (c) Large scale rainfall; (d) Convective rainfall.

Figure 2 Time series of monthly meaned and globally averaged Precipitation- Evaporation (P-E) from December 1992 to January 1993 for various forecast ranges from operational forecastsof the global UM from 00Z and 12Z analyses.

Figure 3 Time series of monthly meaned (a) Precipitation, and (b) Evaporation from December 1992 to January 1993 averaged over the global domain for various forecast ranges from operational forecasts of the global UM from 00Z and 12Z analyses.

Figure 4 Global maps of Precipitation for December, January, and February (DJF) for (a) Jaeger climatology (b) Operational forecasts of the global UM during the assimilation cyle for 1992/93 (c) as (b) but for 1993/94

Figure 5 Global maps of Precipitation during June, July, and August (JJA) for (a) Jaeger climatology (b) Operational forecasts of the global UM during the assimilation cyle for 1992 (c) as (b) but for 1993

Figure 6 Global maps of Precipitation for (a) Operational forecasts of the global UM for T+48 to T+72 accumulations during DJF 1993/94 (b) as (a) but for JJA 1993

Figure 7 As figure 3 but for the Tropics (15N-15S)

Figure 8 As figure 3 but for the Northern hemisphere. (30N-90N)

Figure 9 As figure 3 but for the Southern hemisphere. (30S-90S)

Figure 10 As figure 3 but for the Europe. (10W-40E, 40N-70N)

Figure 11 As figure 3 but for the Atlantic. (75W-15W,30N-60N)

Figure 12 Time series of monthly meaned (a) Precipitation, and (b) Evaporation from January to December 1993 averaged over the LAM domain for operational forecasts of the global and LAM configurations of the UM run from 00Z and 12Z analyses. All fields are interpolated to LAM domain before calculating the area means.

Figure 13 Time series of monthly meaned (a) Dynamic Precipitation, and (b) Convective precipitation from January to December 1993 averaged over the LAM domain for operational forecasts of the global and LAM configurations of the UM run from 00Z and 12Z analyses.

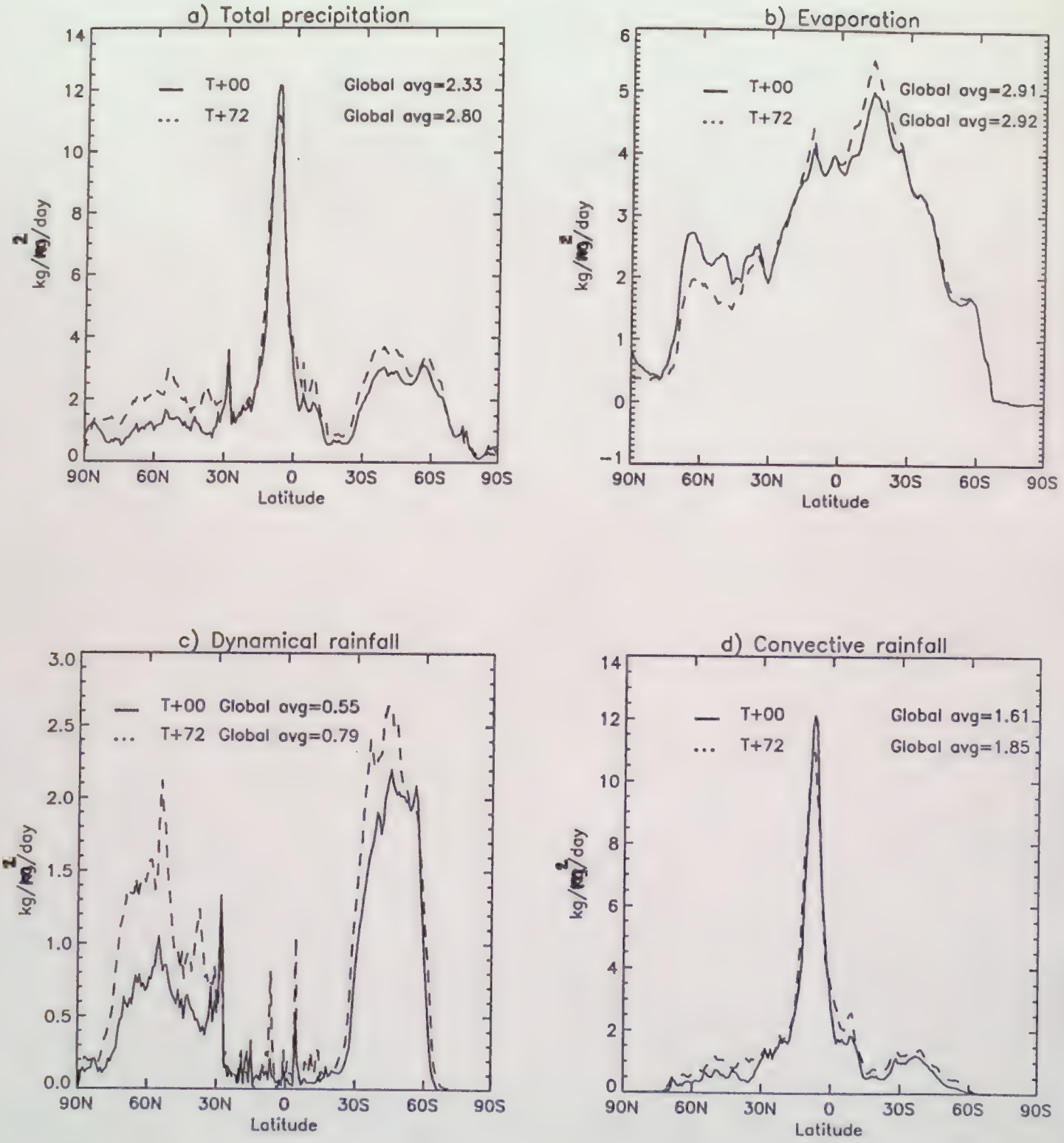

a) Total precipitation
T+00
T+72
Global avg=2.33
Global avg=2.80
kg/m²/day
Latitude
90N
60N
30N
0
30S
60S
90S
b) Evaporation
Global avg=2.91
Global avg=2.92
c) Dynamical rainfall
T+00 Global avg=0.55
T+72 Global avg=0.79
d) Convective rainfall
Global avg=1.61
Global avg=1.85

FIG. 1

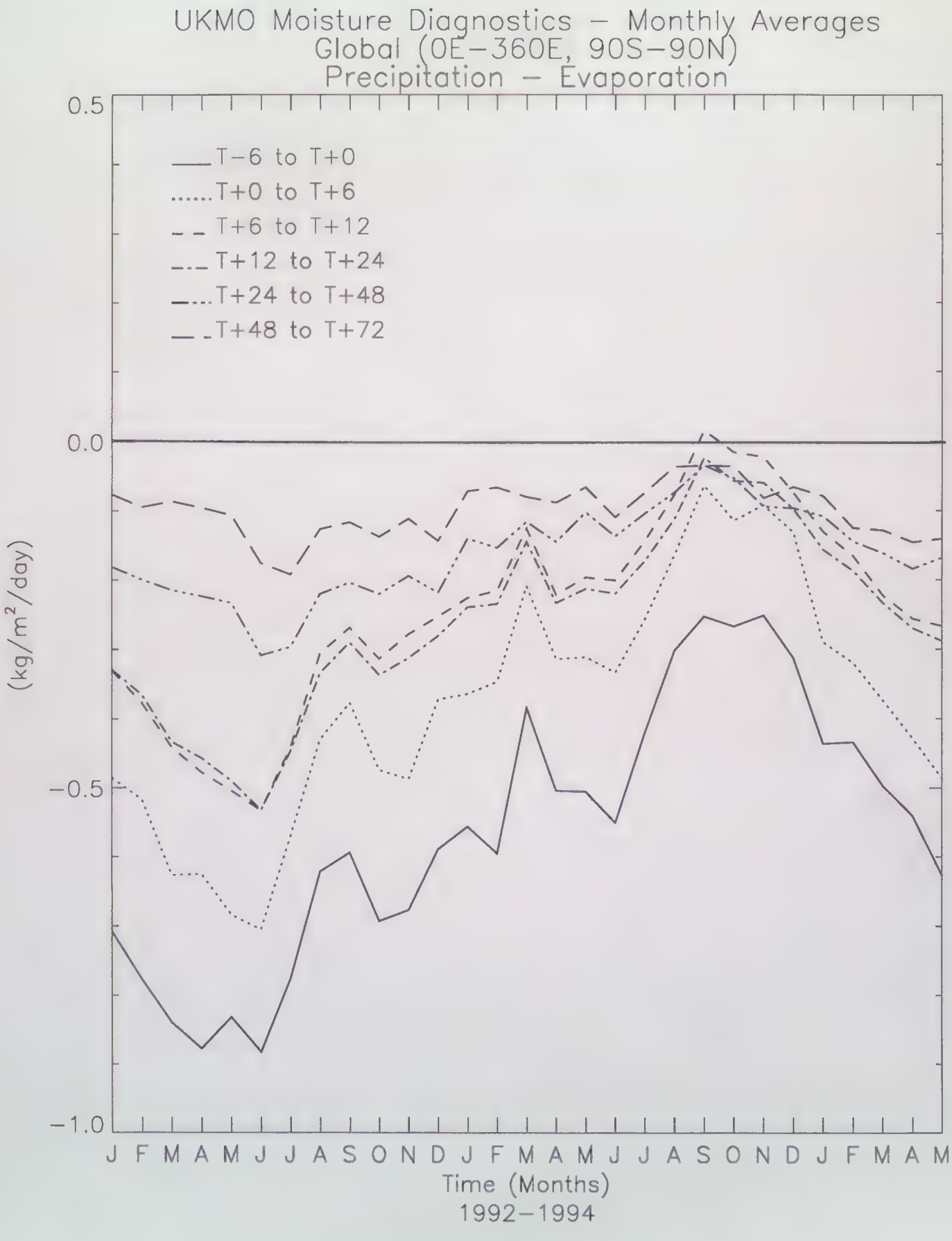
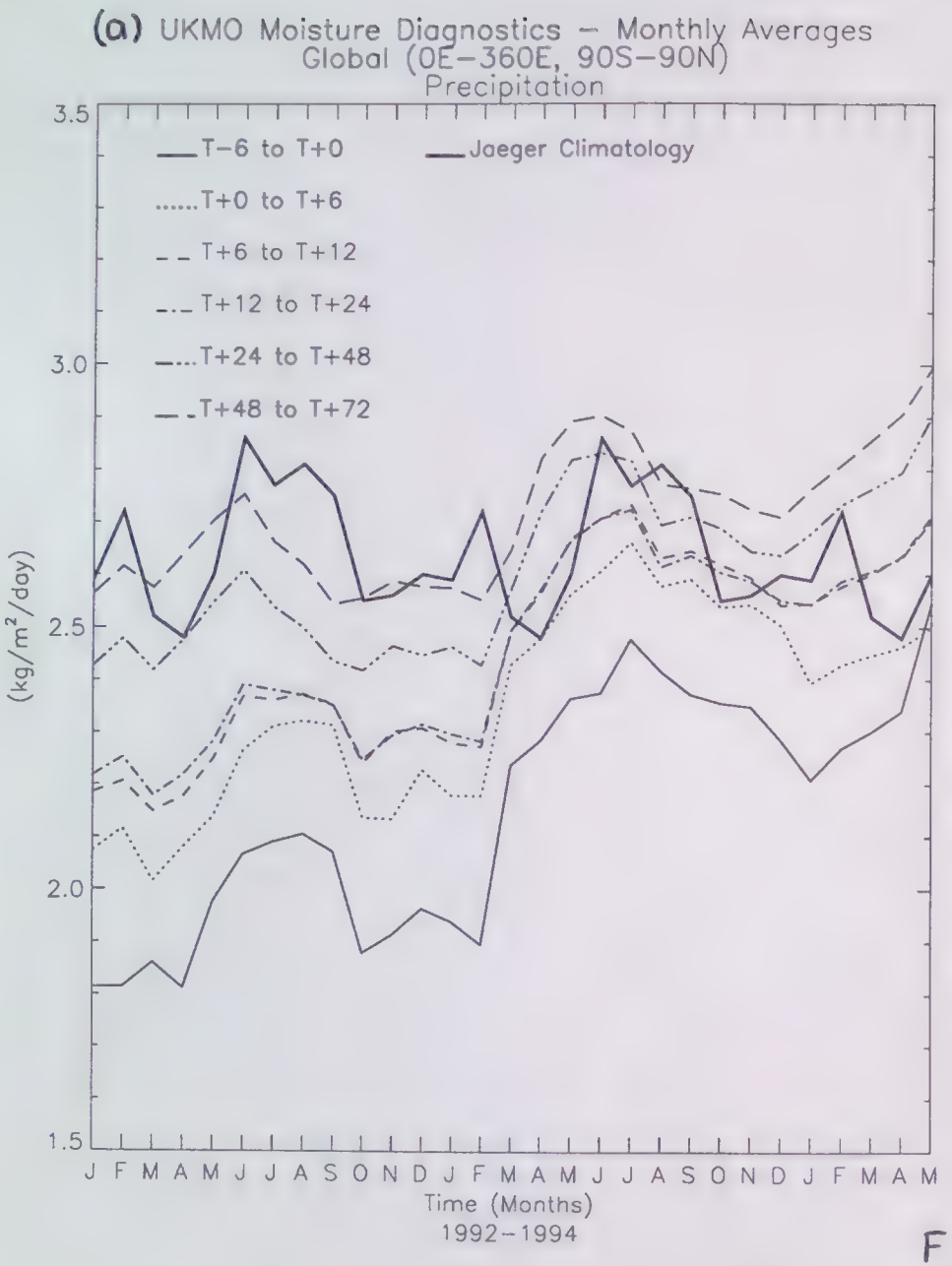

UKMO Moisture Diagnostics – Monthly Averages
Global (0E–360E, 90S–90N)
Precipitation – Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
0.5
0.0
−0.5
−1.0
(kg/m²/day)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG 2.


(a) UKMO Moisture Diagnostics – Monthly Averages
Global (0E–360E, 90S–90N)
Precipitation
T–6 to T+0
Jaeger Climatology
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
3.5
3.0
2.5
2.0
1.5
(kg/m²/day)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

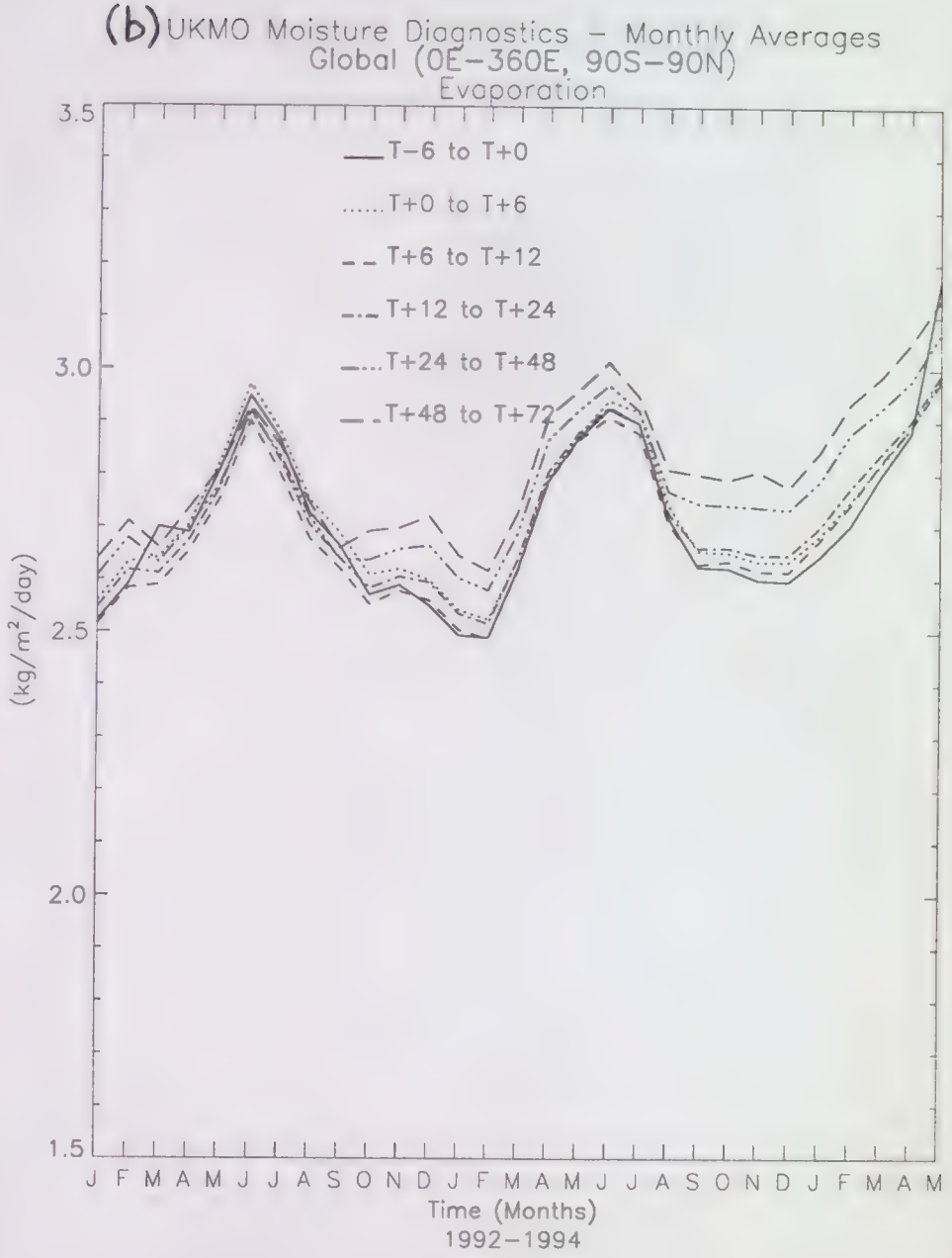
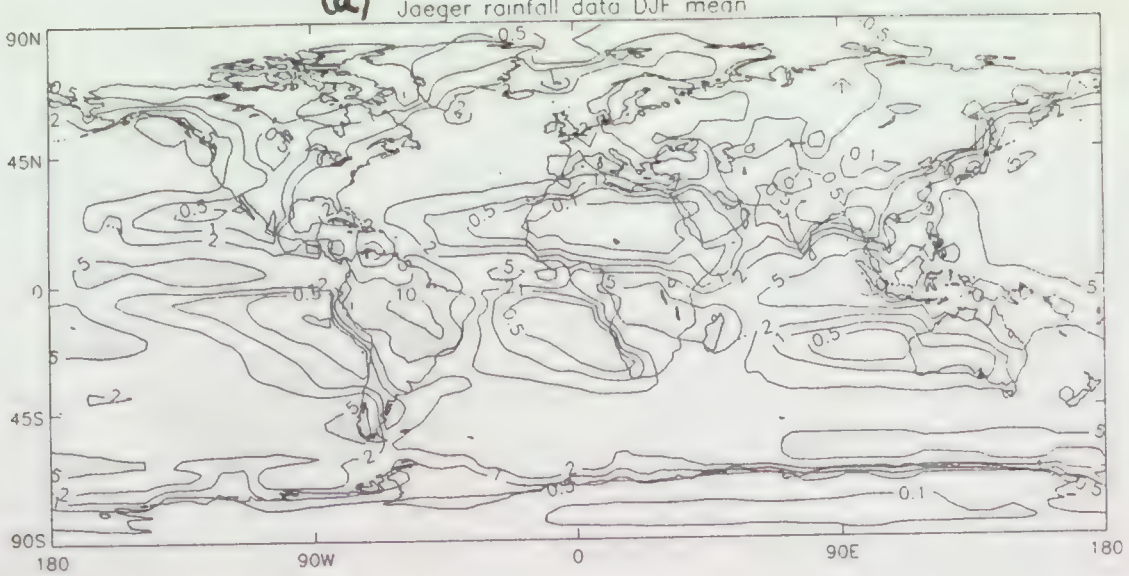

(b) UKMO Moisture Diagnostics – Monthly Averages
Global (0E–360E, 90S–90N)
Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
3.5
3.0
2.5
2.0
1.5
(kg/m²/day)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG 3

(a) Jaeger rainfall data DJF mean



(b) Global Quarterly Means : DJF 1992/93, 00Z and 12Z
Precipitation
T+0

(c) Global Quarterly Means : DJF 1994, 00Z and 12Z
Precipitation
T+0

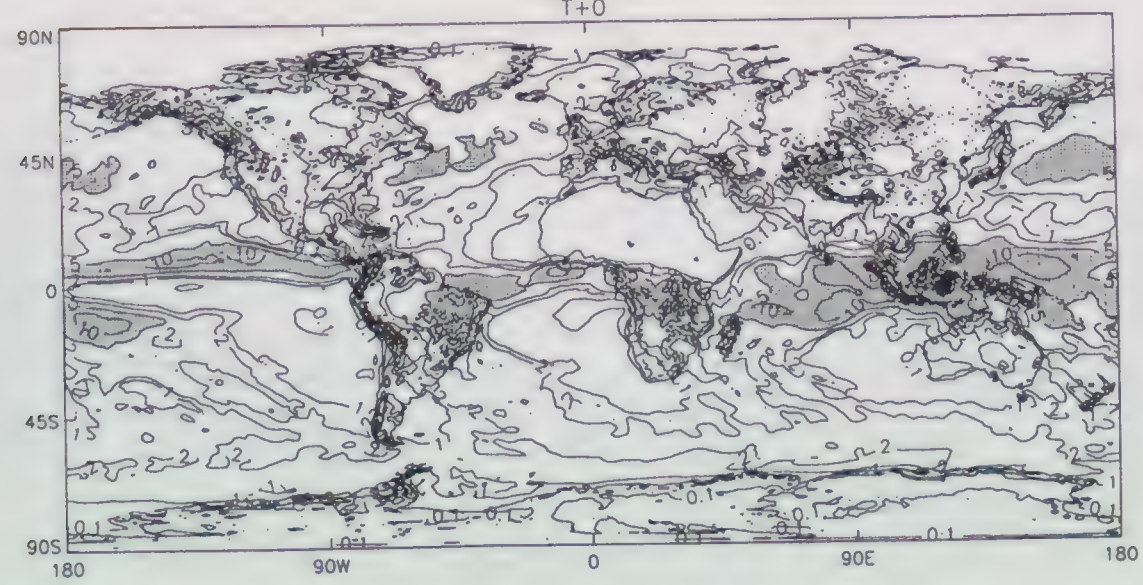
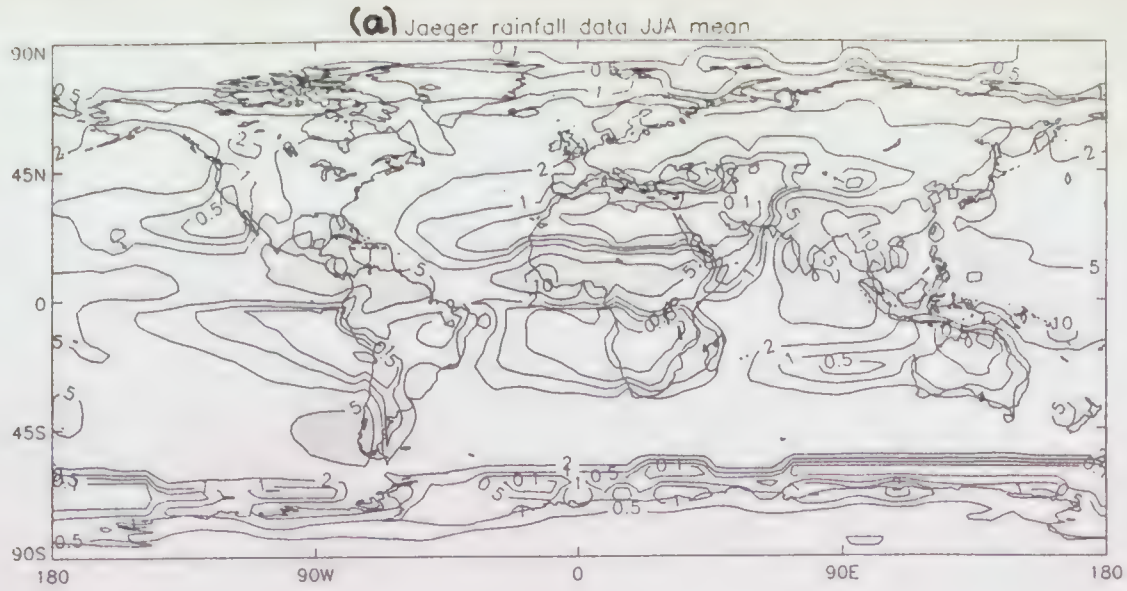
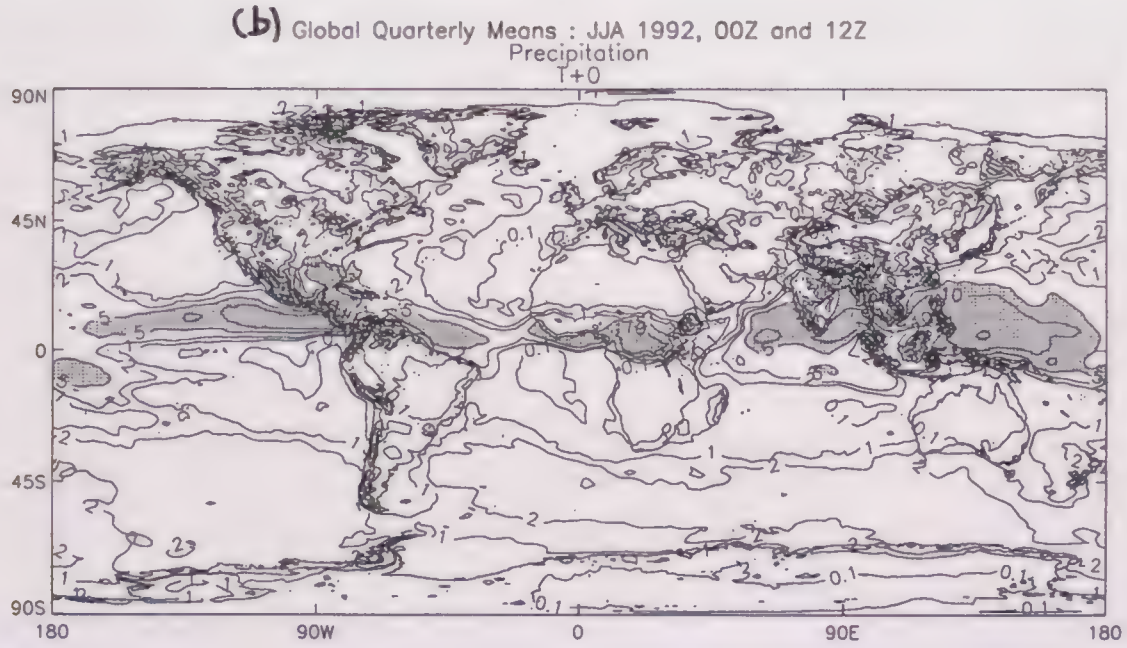


FIG. 4


(a) Jaeger rainfall data JJA mean
90N
45N
0
45S
90S
180
90W
0
90E
180


(b) Global Quarterly Means : JJA 1992, 00Z and 12Z
Precipitation
T+0
90N
45N
0
45S
90S
180
90W
0
90E
180

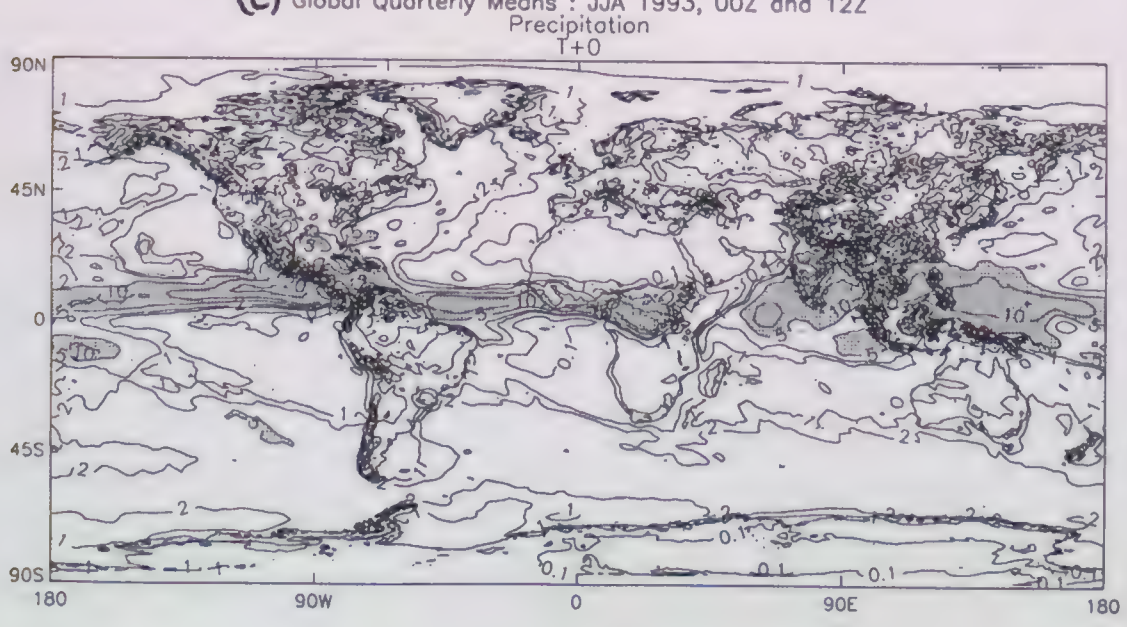
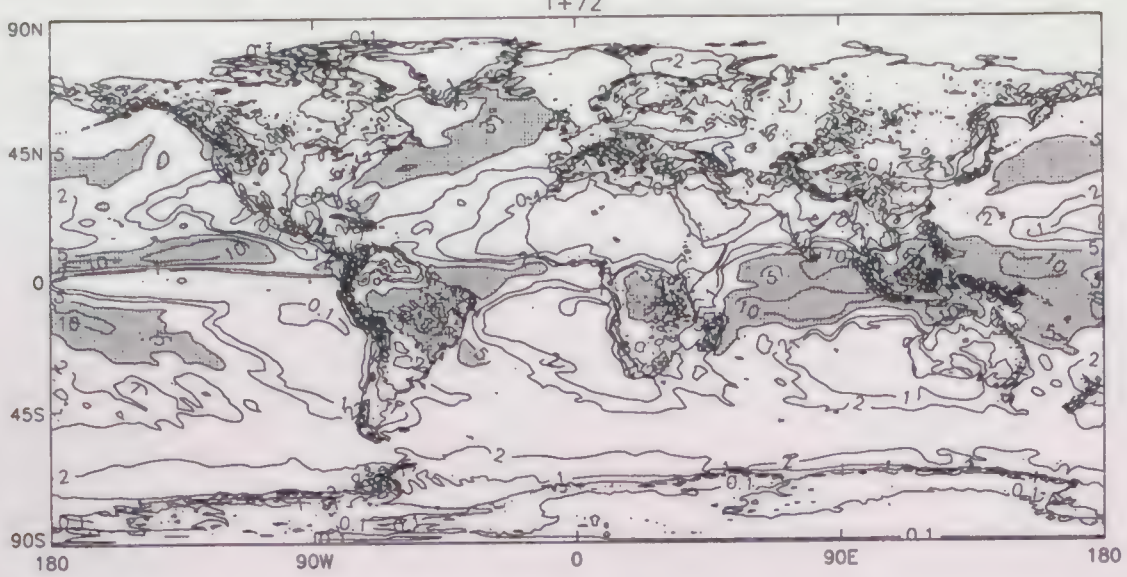

(c) Global Quarterly Means : JJA 1993, 00Z and 12Z
Precipitation
T+0
90N
45N
0
45S
90S
180
90W
0
90E
180

FIG 5

(a) Global Quarterly Means : DJF 1994, 00Z and 12Z
Precipitation
T+72



(b) Global Quarterly Means : JJA 1993, 00Z and 12Z
Precipitation
T+72

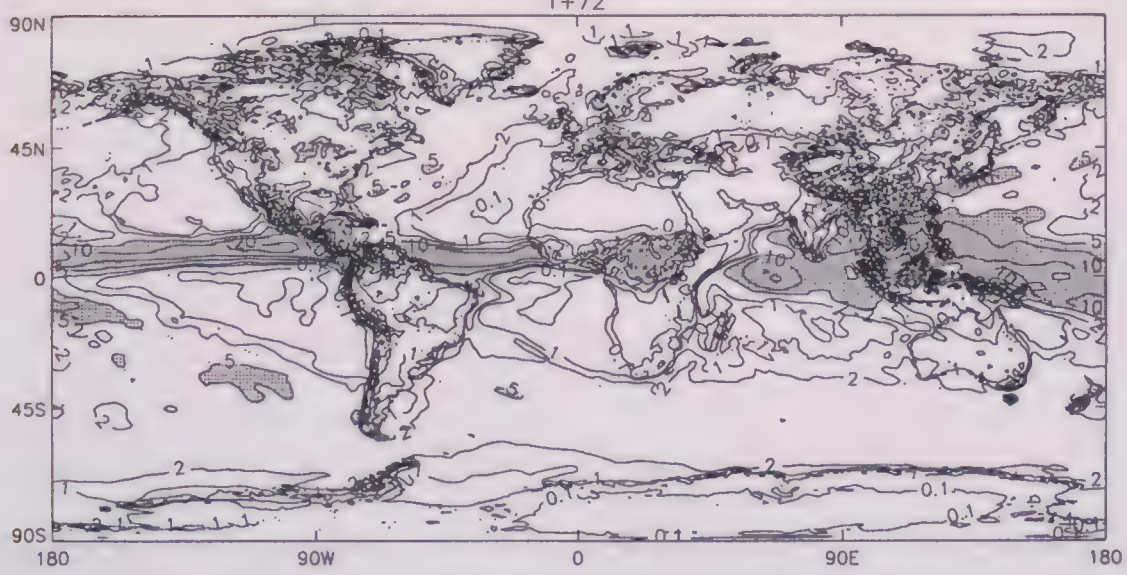
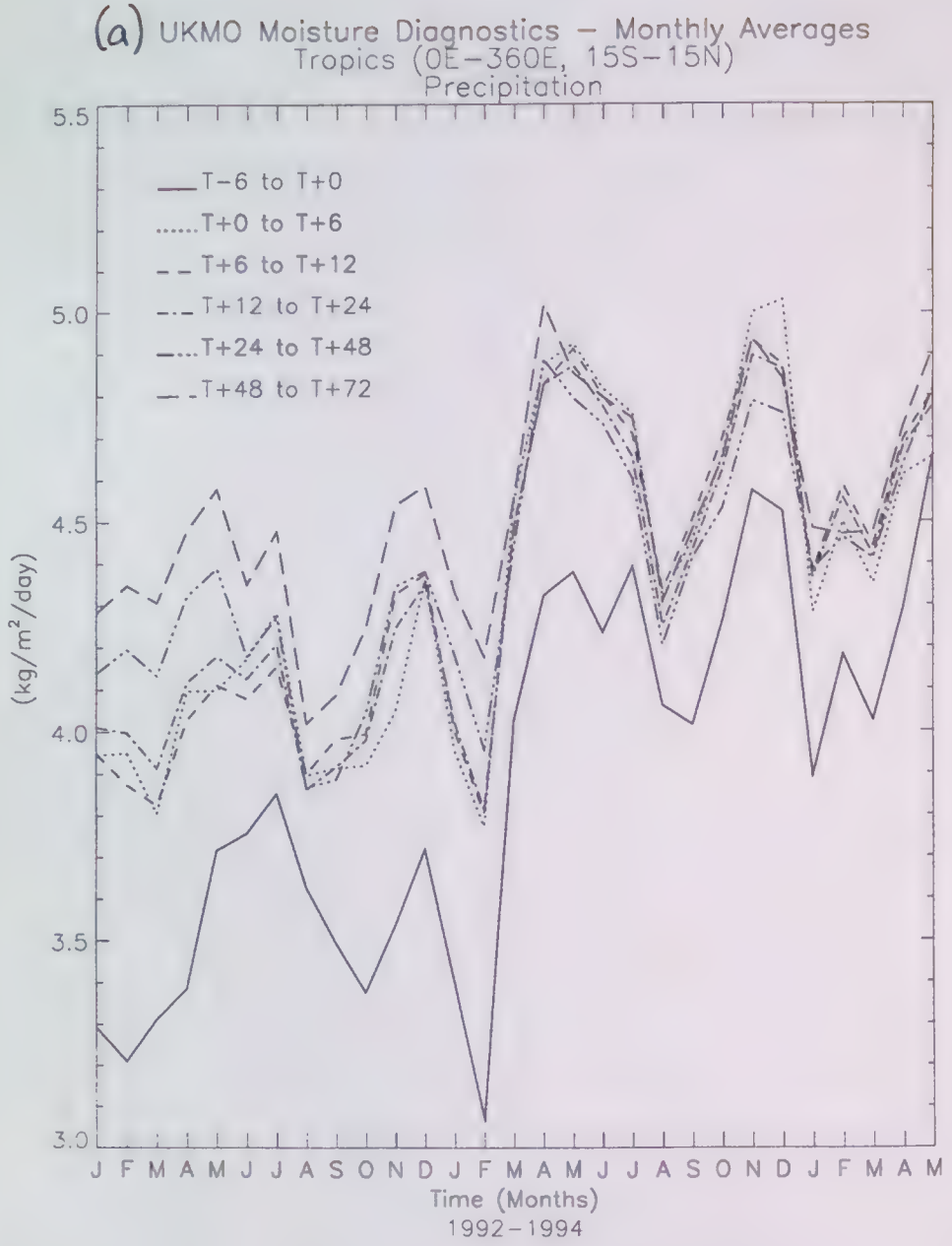


FIG. 6.


(a) UKMO Moisture Diagnostics – Monthly Averages
Tropics (0E–360E, 15S–15N)
Precipitation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
5.5
5.0
4.5
4.0
3.5
3.0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

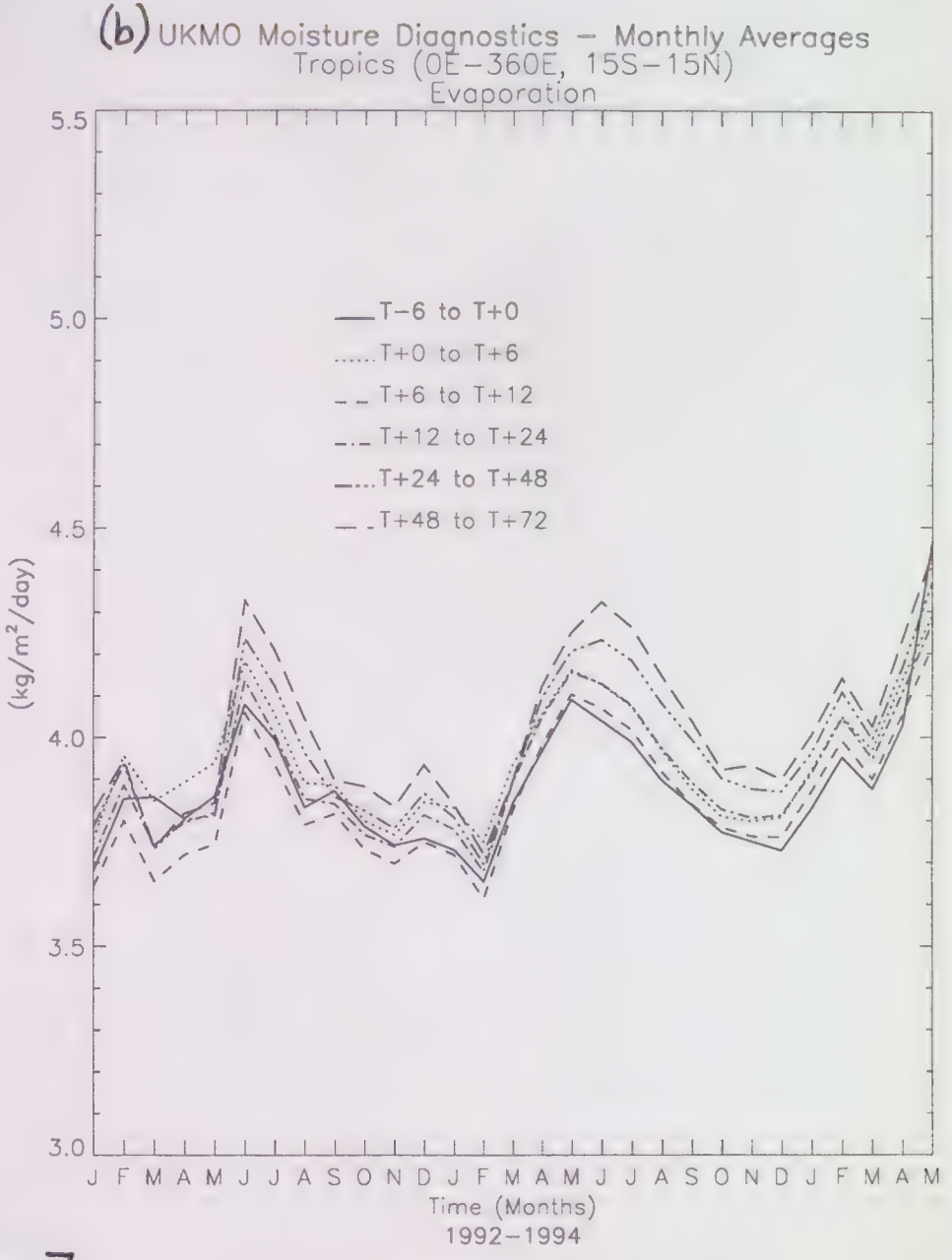

(b) UKMO Moisture Diagnostics – Monthly Averages
Tropics (0E–360E, 15S–15N)
Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
5.5
5.0
4.5
4.0
3.5
3.0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG. 7

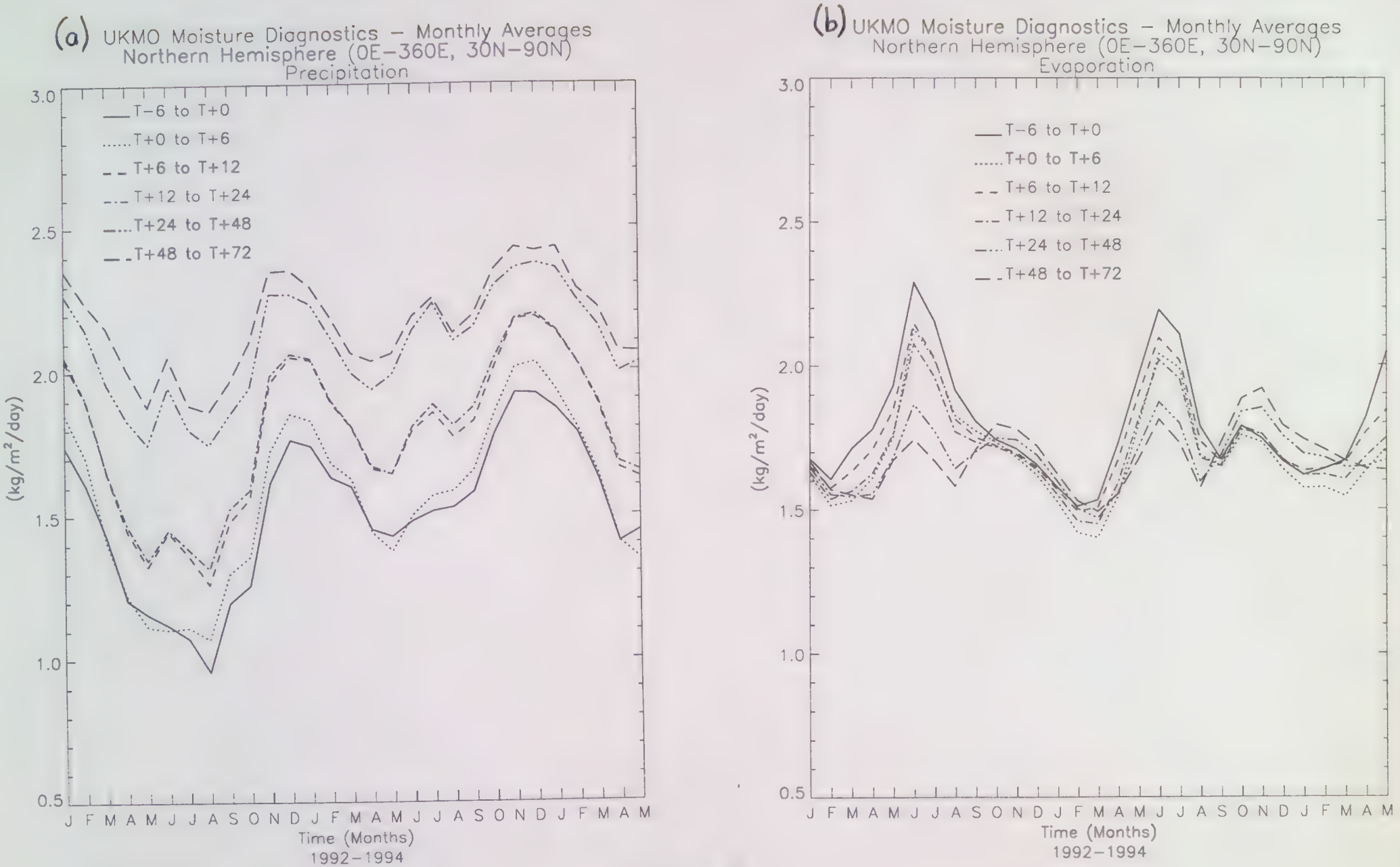

(a) UKMO Moisture Diagnostics – Monthly Averages
Northern Hemisphere (0E–360E, 30N–90N)
Precipitation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
3.0
2.5
2.0
1.5
1.0
0.5
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994
(b) UKMO Moisture Diagnostics – Monthly Averages
Northern Hemisphere (0E–360E, 30N–90N)
Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
3.0
2.5
2.0
1.5
1.0
0.5
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG. 8

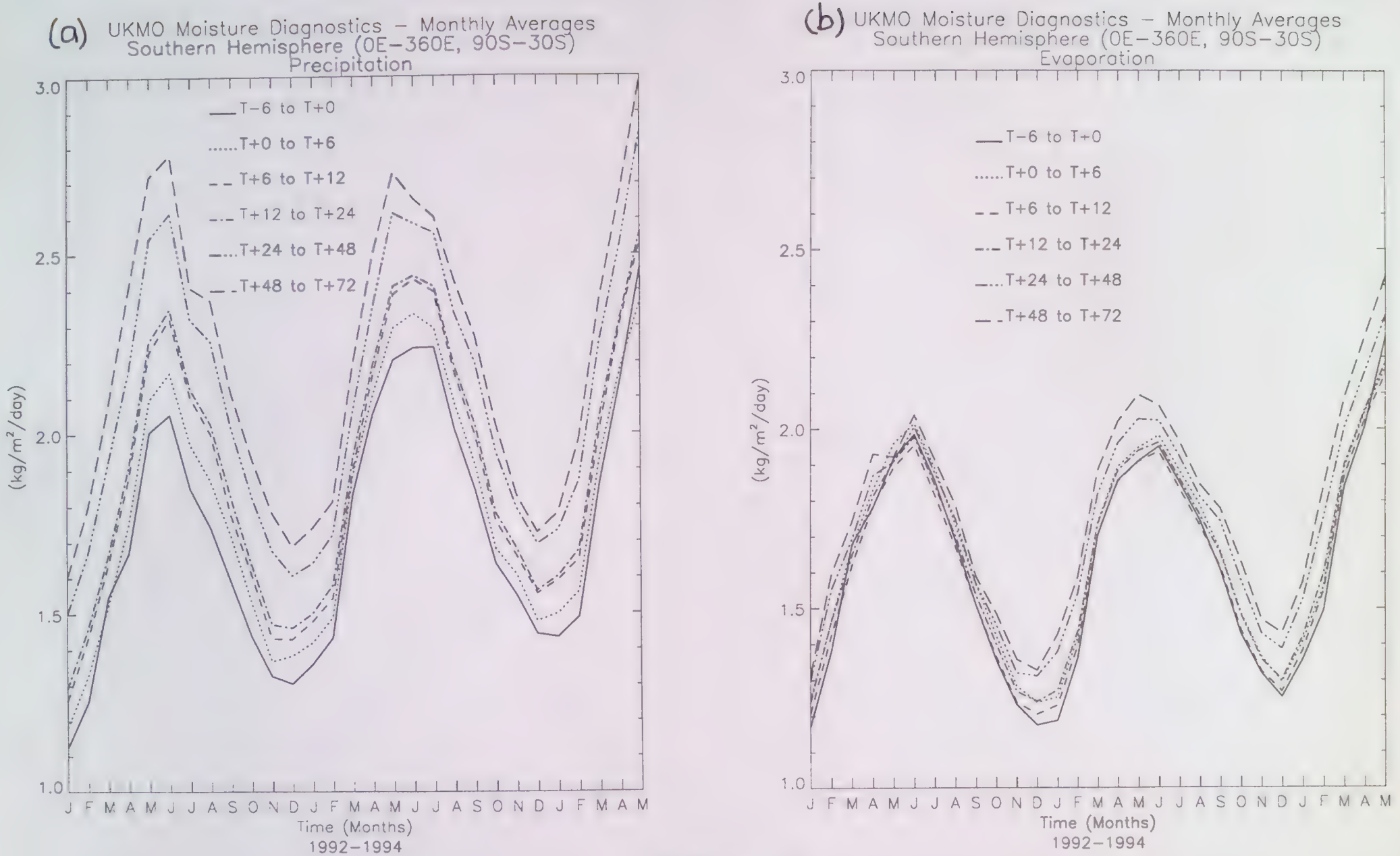

(a) UKMO Moisture Diagnostics – Monthly Averages
Southern Hemisphere (0E–360E, 90S–30S)
Precipitation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
3.0
2.5
2.0
1.5
1.0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994
(b) UKMO Moisture Diagnostics – Monthly Averages
Southern Hemisphere (0E–360E, 90S–30S)
Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
3.0
2.5
2.0
1.5
1.0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG. 9

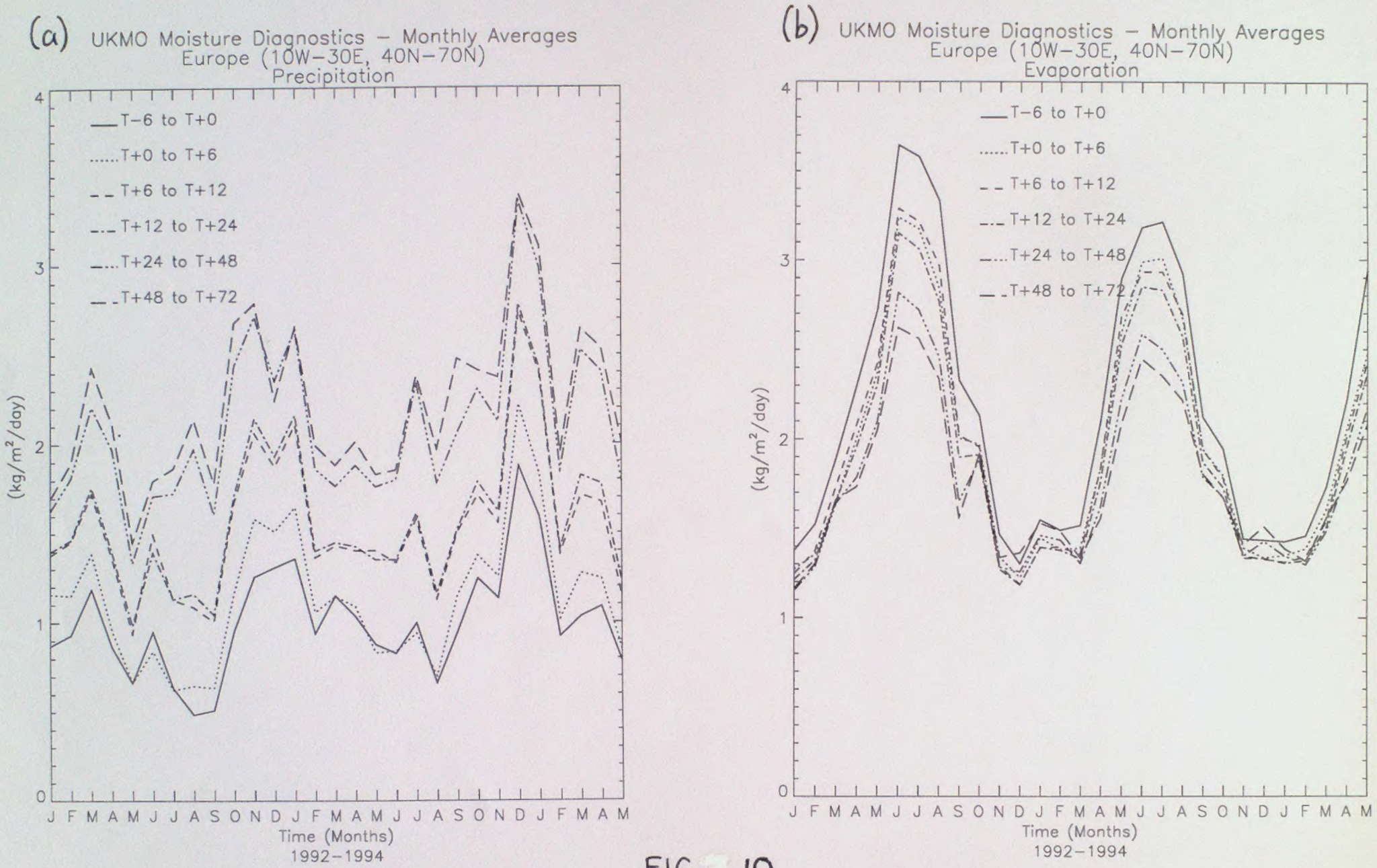

(a) UKMO Moisture Diagnostics – Monthly Averages
Europe (10W–30E, 40N–70N)
Precipitation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
0
1
2
3
4
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994
(b) UKMO Moisture Diagnostics – Monthly Averages
Europe (10W–30E, 40N–70N)
Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
0
1
2
3
4
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG 10

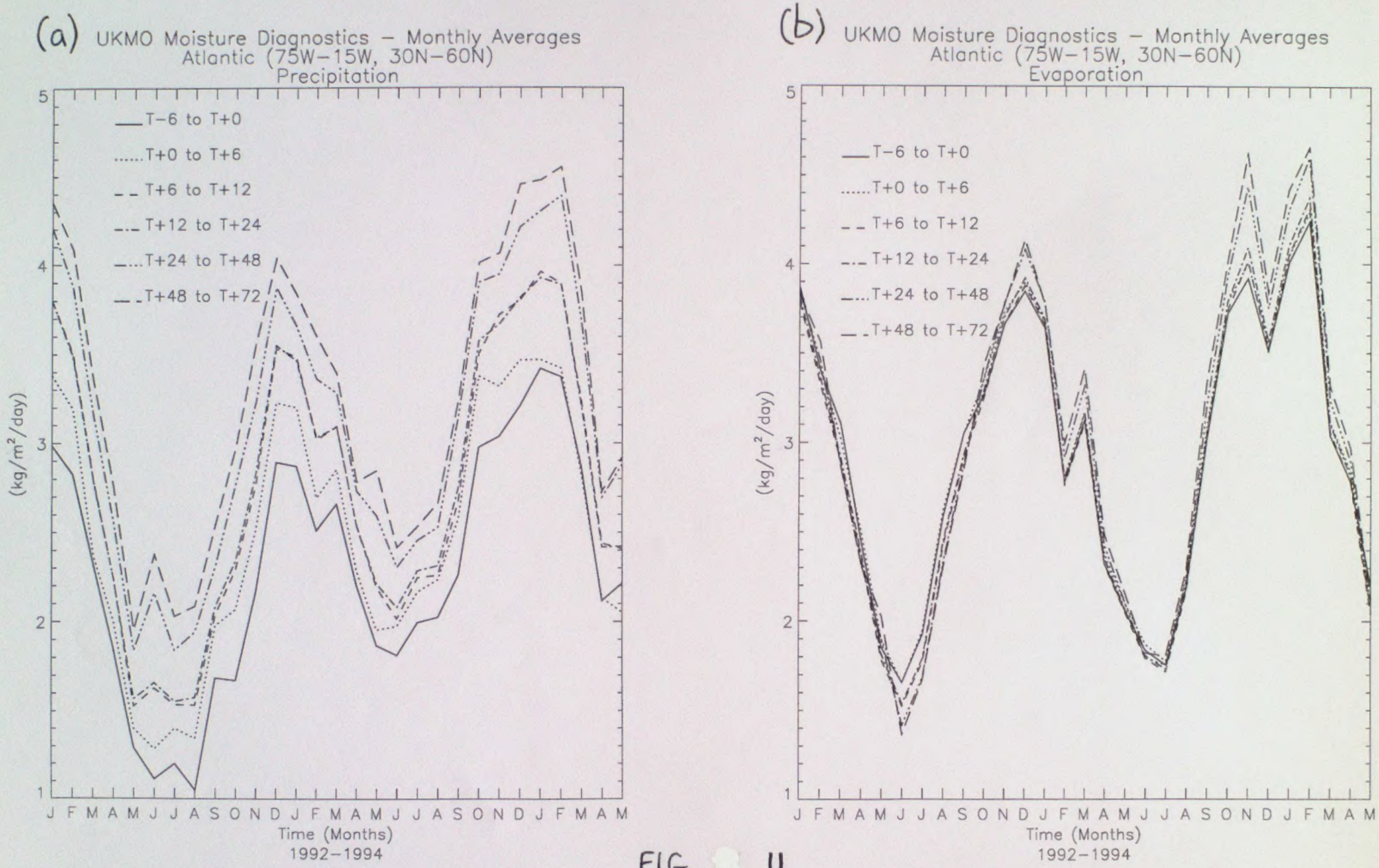
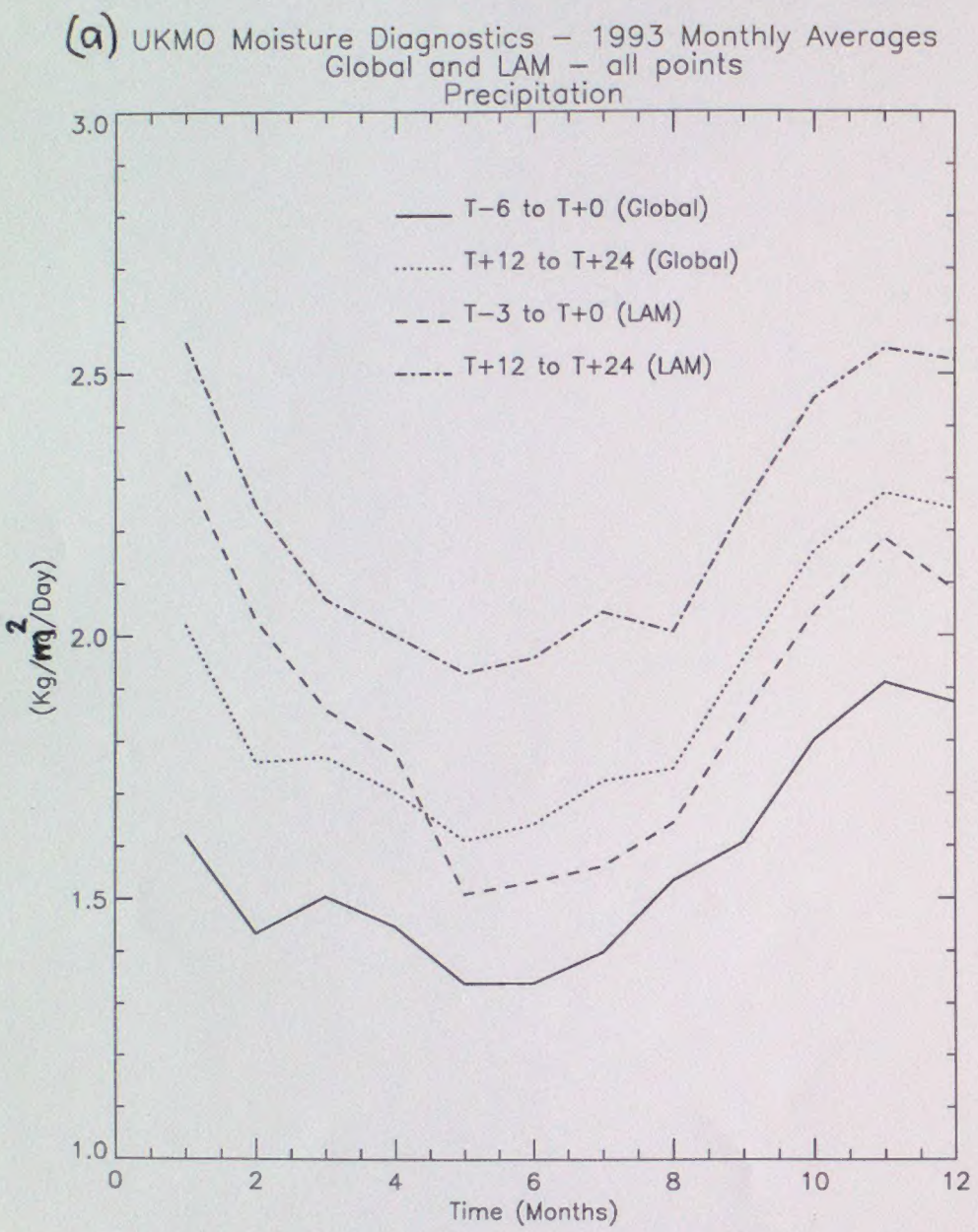

(a) UKMO Moisture Diagnostics – Monthly Averages
Atlantic (75W–15W, 30N–60N)
Precipitation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
1
2
3
4
5
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994
(b) UKMO Moisture Diagnostics – Monthly Averages
Atlantic (75W–15W, 30N–60N)
Evaporation
T–6 to T+0
T+0 to T+6
T+6 to T+12
T+12 to T+24
T+24 to T+48
T+48 to T+72
(kg/m²/day)
1
2
3
4
5
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
Time (Months)
1992–1994

FIG 11


(a) UKMO Moisture Diagnostics – 1993 Monthly Averages
Global and LAM – all points
Precipitation
T–6 to T+0 (Global)
T+12 to T+24 (Global)
T–3 to T+0 (LAM)
T+12 to T+24 (LAM)
(Kg/m2/Day)
Time (Months)

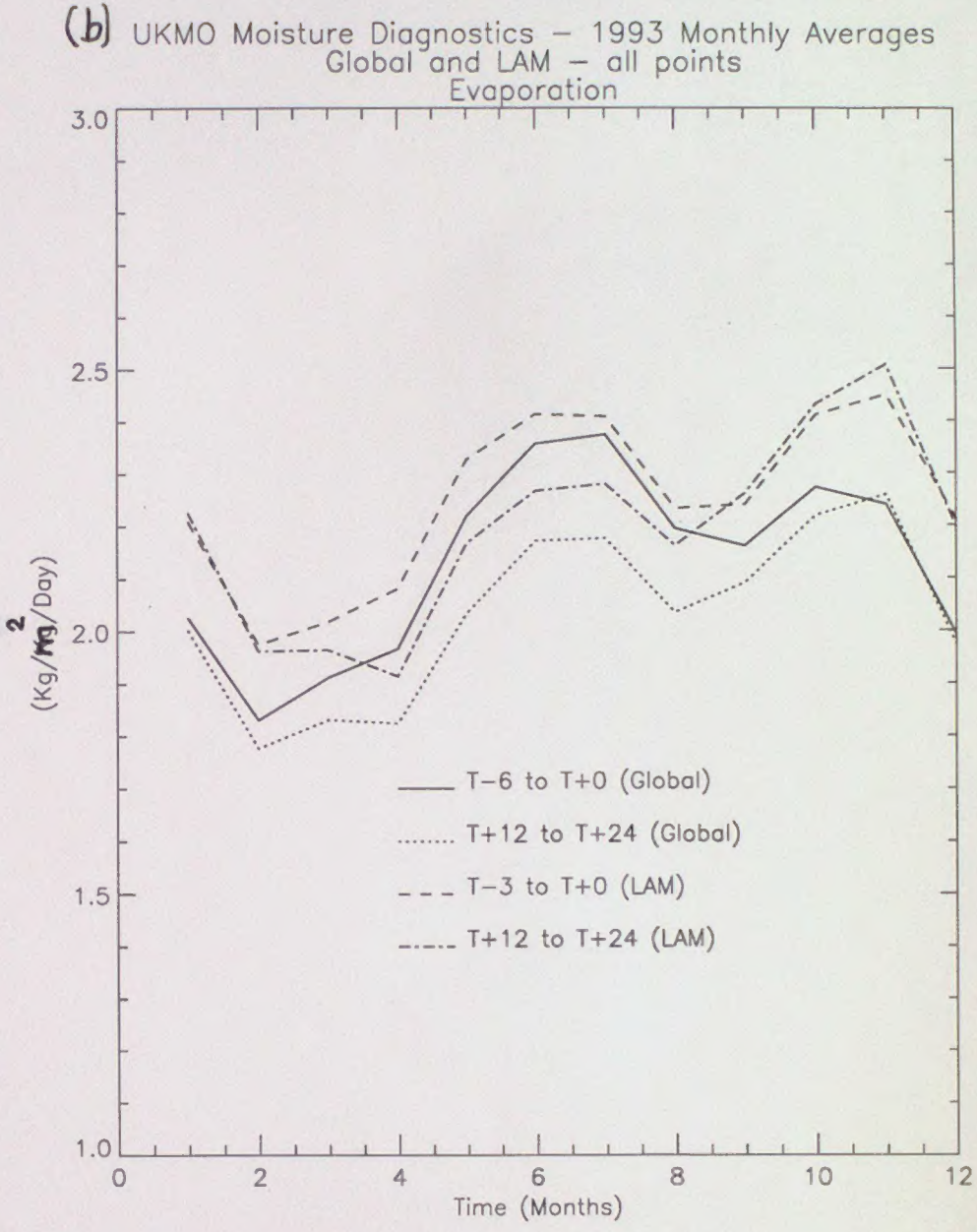
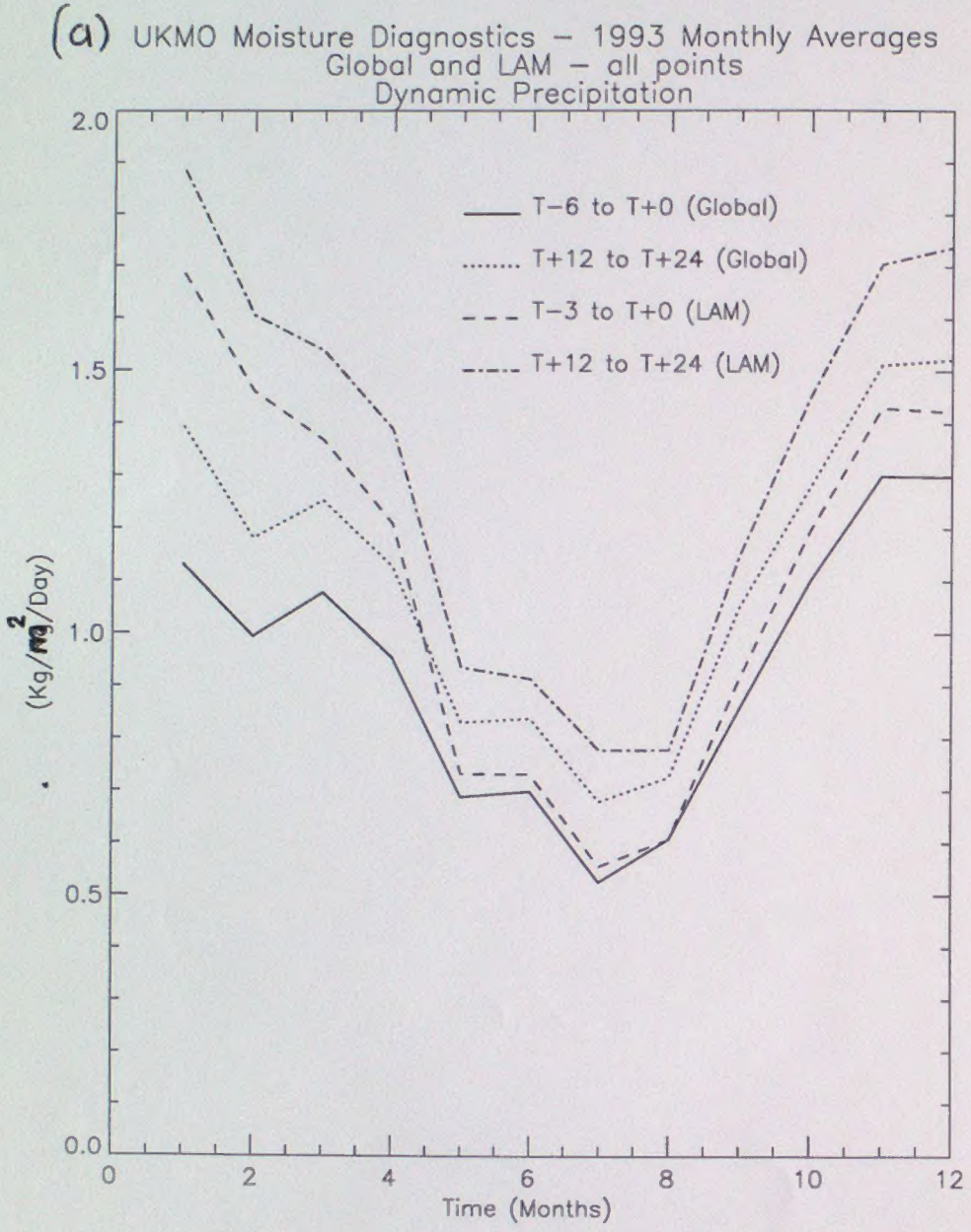

(b) UKMO Moisture Diagnostics – 1993 Monthly Averages
Global and LAM – all points
Evaporation
T–6 to T+0 (Global)
T+12 to T+24 (Global)
T–3 to T+0 (LAM)
T+12 to T+24 (LAM)
(Kg/m2/Day)
Time (Months)

FIG 12


(a) UKMO Moisture Diagnostics – 1993 Monthly Averages
Global and LAM – all points
Dynamic Precipitation
T–6 to T+0 (Global)
T+12 to T+24 (Global)
T–3 to T+0 (LAM)
T+12 to T+24 (LAM)
(Kg/m²/Day)
Time (Months)
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12

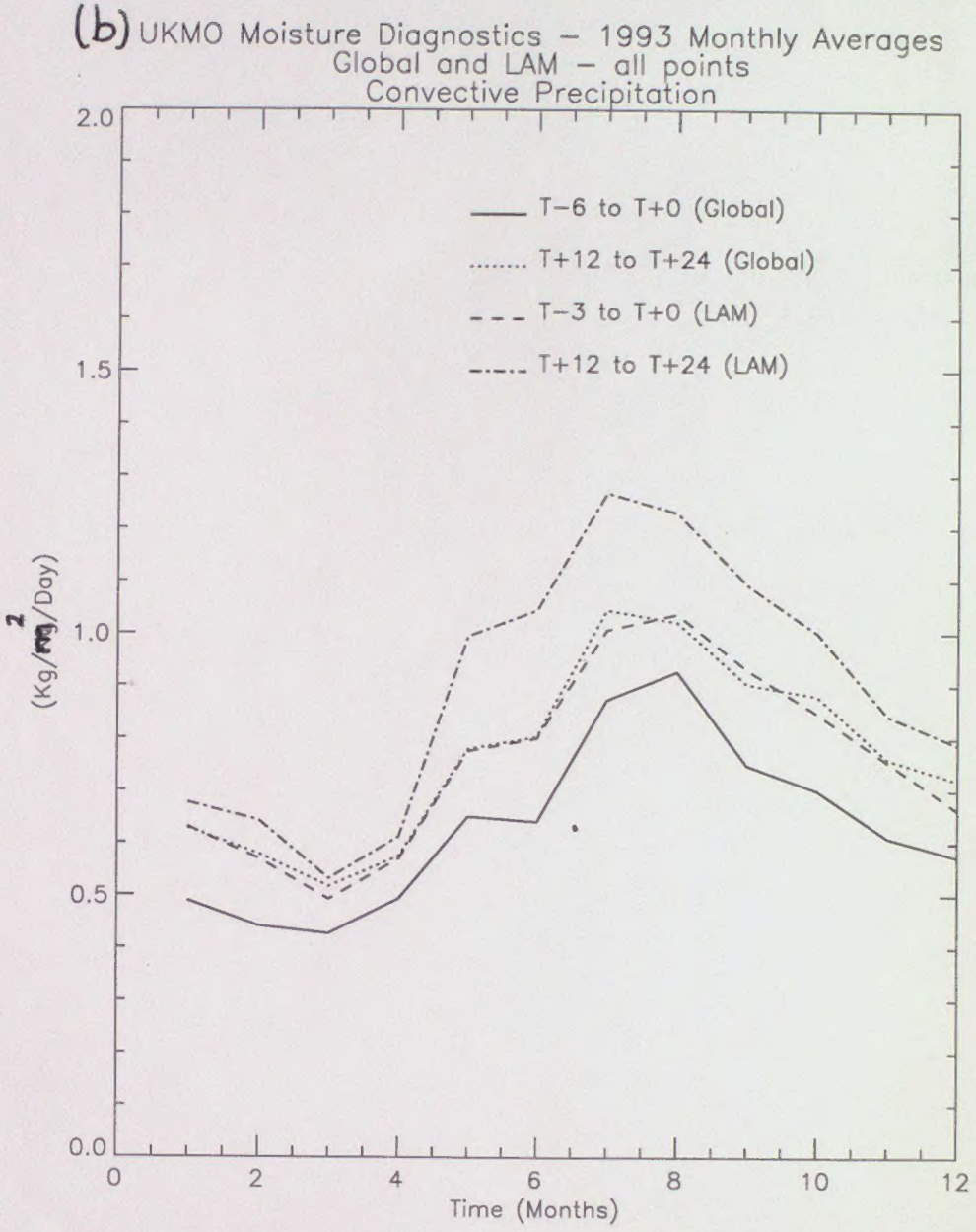

(b) UKMO Moisture Diagnostics – 1993 Monthly Averages
Global and LAM – all points
Convective Precipitation
T–6 to T+0 (Global)
T+12 to T+24 (Global)
T–3 to T+0 (LAM)
T+12 to T+24 (LAM)
(Kg/m²/Day)
Time (Months)
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12

FIG 13